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SigmaPipe as an education tool for engineers

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ABSTRACT

Chemical engineering students are trained to solve problems involving pipe flow and heat transfer at a fundamental level. However, when they confront such problems as graduates, they often do not have time to perform such calculations. Although many commercial software packages exist, most (i) require licence fees and (ii) have a significant learning time. Consequently, commercial packages are generally not a realistic choice for the average plant engineer wanting to solve a quick, "once off" problem.

SigmaPipe is a new simulation tool that blends video game-like 3D pipe geometry with pressure drop/heat transfer calculations. It was developed as a "community service" project specifically to fill the abovementioned gap: it is free, universal and easy to use. It is envisioned that a key factor supporting SigmaPipe's uptake in industry will be creating a bond between the software and the student during undergraduate education.

Accordingly, to assess SigmaPipe's potential use in education, evaluation projects were conducted at Curtin University (WA, Australia) and Monash University (Victoria, Australia). The different methodologies and outcomes of the projects are presented here. Student feedback was generally positive and valuable ideas were generated. Importantly, the feedback has already been incorporated into the next version of SigmaPipe.

1. Introduction

Engineers often need to address issues associated with fluid flow and heat transfer in piping systems. Traditional approaches involving hand calculations and/or spreadsheets are largely giving way to smart applications that reduce the time requirement and the potential for errors. This type of software tool is generally able to simulate piping flow systems to determine factors such as pressure drop, maximum possible flow, temperature/phase changes and installed valve characteristics for a given system. Commercial software in this area is reasonably well established–packages currently on offer include the following:

1. Pipe Flow Expert from Pipe Flow, UK (www.pipeflow.com). This system deals very well with pipe flow situations and has been available since around 2004. It has a Windows-style interface that includes piping isometrics, but not a full 3D visualisation. A "lite" version user licence will cost around $US800 and full versions more than $US2000.
2. Korf Hydraulics from Korf Technology, UK (www.korf.co.uk) has broadly similar capabilities, including a general Windows-style interface with piping isometrics. A single-user licence will cost around $US2000 and a site licence around $US8000.
3. AFT Fathom from Applied Flow Technology Corp, USA (www.aft.com) performs a similar function and includes

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capability for dealing with non-settling slurries. Licence fees are thought to be broadly similar to those quoted above.

This is not an exhaustive list – Korf Technology (2015) lists some 40 fluid flow packages – the intention is merely to illustrate the type of software landscape a graduate engineer might encounter when investigating options for this type of calculation. These are commercial packages with significant licence fees. Sometimes this approach does not quite fit because the combination of cost and learning requirements renders it unattractive. Under such circumstances, SigmaPipe (as reported here) represents a possible alternative. To place this in context, it is helpful consider how the perceived need for SigmaPipe arose.

In the engineering support section of an operating plant (HIsmelt, Kwinana 2003–2008) there were several young engineers who, from time to time, needed to perform calculations for orifice sizing and/or pressure drop estimation. An overriding consideration was always time: they needed reliable results fast. There was no question of buying a commercial package and learning how to use it. In any case, the engineers in question might not need such a calculation again for 6 months or more. If they had bought and mastered a commercial package, they would (6 months later) most likely have forgotten how to use it.

How, then, could these engineers get the job done? In this particular case, it became known that one individual (the lead author) had some, albeit not particularly user-friendly, Excel software for performing such calculations. It became easier to ask this person to do the calculations, and this soon became the default mode of operation. Of course, all is well if such a person is available and willing to help when needed. However, this cannot always be the case. Hence there was a gap—what piece of software would allow these young, time-poor engineers to do such calculations themselves with confidence and a minimum of fuss?

Apart from the need for zero cost and a high level of user-friendliness, the greatest requirement is familiarity. If a piece of software has not been used for an extended period, then there is an “activation hump” to get over before it can be used efficiently again. If this hump is perceived to be too great, then the solution breaks down. This is why it was thought that exposure to suitable software during the engineer’s undergraduate education would be critical. If teaching were to incorporate SigmaPipe as a normal part of the course, in the same way that process simulators like Aspen Hysys and Aspen Plus are, then activation issues are dealt with outside the pressurised, on-the-job, graduate environment. It would become quite natural for the young engineer to reach for and use a familiar tool with confidence and competence. Even if such a tool were needed only occasionally, it does not really matter if sufficient familiarity were retained from undergraduate days.

Setting aside graduate concerns for the moment, Campbell and Latulippe (2015) pointed out two benefits of incorporating commercial-quality software in undergraduate fluid mechanics teaching compared to the use of manual calculations alone. First, it may lead to a deeper understanding of fluid flow concepts and consequently an improved ability to solve practical problems. Second, it allows the convenient analysis of much more complicated, realistic systems. Fraser et al. (2007) also argued the benefit of using fluid flow simulation software early in the course for concept development, which is distinct from its use as a calculation tool by more senior students. It should be noted that teaching commercial heat transfer and pipe flow software, like the abovementioned packages, appears to be uncommon in undergraduate chemical engineering courses (Campbell and Latulippe, 2015).

With the preceding context in mind, SigmaPipe was developed by the lead author with the following key design principles:

- It is essentially a community service project (the engineering community in this case).
- It is designed as a standard Windows application in terms of menus, editing and so on.
- The user must be able to create and manipulate pipe-related objects in 3D space with ease.
- Flow solutions are essentially 1D in nature—it is not a CFD package.
- As far as possible, physical reality must be reflected (e.g. if pipes heat up, they expand; if sonic limitations like choked flow occur, they must be dealt with seamlessly).
- Common elements (e.g., valves, pumps and heat exchangers) must be included.

Based on these guiding principles, coding started in early 2009. The first major release version, a free download from www.sigmapipe.com, went online in January 2013 and the second (SigmaPipe 2.0) in January 2014 as a Windows-based application suitable for Windows 7 or later (it will also run on Windows 8 and Windows 10). The two evaluation projects reported in this article were performed using Version 2.2. Improvements to the software have been made as a result of the evaluation projects, and these are discussed later.

The aims of this study are to:

1. Provide a high-level overview of SigmaPipe, noting particularly its user interface features, calculation and reporting capabilities, and its underlying assumptions.
2. Evaluate the software usability of SigmaPipe as perceived by undergraduate chemical engineering students for the purpose of guiding its future development.
3. Evaluate a scenario-based learning activity featuring SigmaPipe aimed at developing high level problem solving skills in a third-year undergraduate Process Design unit.
4. Implement improvements to the software based on the evaluation projects and reflect on possible further developments.

The second and third aims were addressed in projects conducted at Curtin University and Monash University, respectively, both in 2014.

The framework employed in this project is the Case Study, which is used when there is a need for the validation of findings emerging from an analysis of a single case or phenomena (Case and Light, 2011; Flyvbjerg, 2001). It is an in-depth examination of a distinct, single instance of a class of phenomena such as an activity, group, individual or event and often involves a small sample size to allow the researcher to look into situations for logical deductions of the type “if this holds for this case, then it will hold for other cases” (Shepard and Greene, 2003).